Impacts of the Lake Elsinore Advanced Pumped-Storage (LEAPS) Project on Water Quality in Lake Elsinore

Key Findings of Final Report Prepared for the Federal Energy Regulatory Commission, Washington DC, Project No. 14227[1]

Executive Summary

This study evaluated the impacts on water quality in Lake Elsinore from operation of the Lake Elsinore Advanced Pumped-Storage (LEAPS) project at different lake levels, and from storage of water in the Upper Reservoir (Anderson, 2019). The study was conducted in response to needs highlighted by the Santa Ana Regional Water Quality Control Board and identified in the *Response to Additional Study Requests* prepared by the Federal Energy Regulatory Commission (FERC) (FERC, 2018). An analysis was also included that assessed how LEAPS may improve water quality in Lake Elsinore compared with existing conditions.

The key conclusions of the study were as follows:

Finding 1: The operation of LEAPS with supplementation up to 15,000 acre-feet of State Water Project (SWP) water significantly increased the lake level and reduced volume-weighted concentrations of total dissolved solids (TDS), nutrients, chlorophyll a, and microcystin across a range of lake elevations, with the greatest relative improvement achieved at lowest initial surface elevation and poorest water quality of three water surface elevations evaluated.

Finding 2: Initial storage of water in the Upper Reservoir was found to have variable effects on water quality that increased with increasing retention time. Regular weekday pumping and hydropower generation, with a retention time of water in the Upper Reservoir of 1-2 days, resulted in water quality that followed quite closely that of Lake Elsinore. Increasing the duration of storage in the Upper Reservoir from approximately 2 days over the weekend under a typical

[1] For full report, please see: http://leapshydro.com/wp-content/uploads/2019/02/V18-E1-1-Study-4-7-Impact-of-LEAPS-on-Water-Quality.pdf

schedule or longer yielded more significant differences, especially with respect to concentrations of chlorophyll a and dissolved oxygen (DO).

Finding 3: While not proposed as part of the license application for the project, augmentation to DO concentrations in return flows to the lake during hydropower generation was predicted to provide significant additional ongoing benefits to water quality beyond initial dilution with SWP water.

Study Approach

The study used the 3-D hydrodynamic-water quality Aquatic Ecosystem Model (AEM3D) (Hodges and Dallimore, 2016), and builds upon previous studies addressing potential impacts of LEAPS operation on Lake Elsinore (Anderson, 2006a,b; Anderson, 2007a,b).

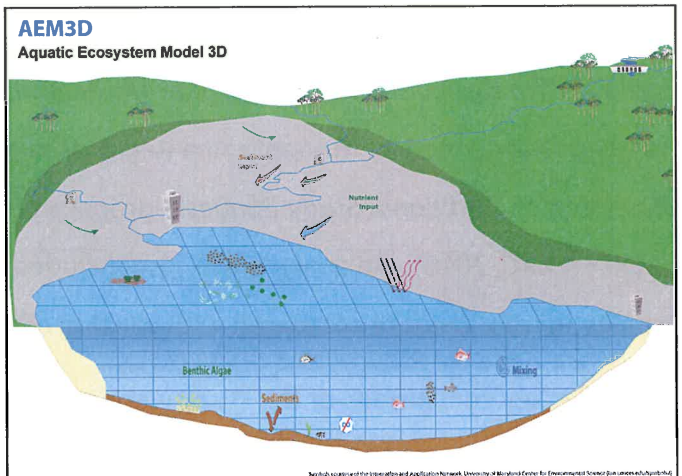

Fig. 1. Schematic representing AEM3D model.

Modelling

The model simulates velocity, temperature, salinity, nutrients and biogeochemical reactions in surface waters (Fig. 1). The model grid for Lake Elsinore was developed from the hydroacoustic bathymetric survey conducted in 2010 (Anderson, 2010) and revised to 1255 ft based upon satellite imagery at known lake surface elevations. Bathymetry for the Upper Reservoir was taken from design documents. A horizontal grid of approximately 130 square feet was selected to represent the lateral dimensions of Lake Elsinore and the Upper Reservoir following consideration of spatial resolution, and number and duration of simulations needed for the study. The vertical dimension across the domain that included both Lake Elsinore and the Upper Reservoir was represented by 66 layers that were roughly 1 foot thick for the uppermost 40 feet (representing the approximate maximum depth of Lake Elsinore) that then smoothly grade to 6.5 feet in thickness at 106.6 feet in depth and remain at 6.5 feet in thickness to a depth of 165.7 feet for the vertical discretization of the Upper Reservoir. This results in a total of 240,004 cells in the computational domain at full pool (Fig. 2).

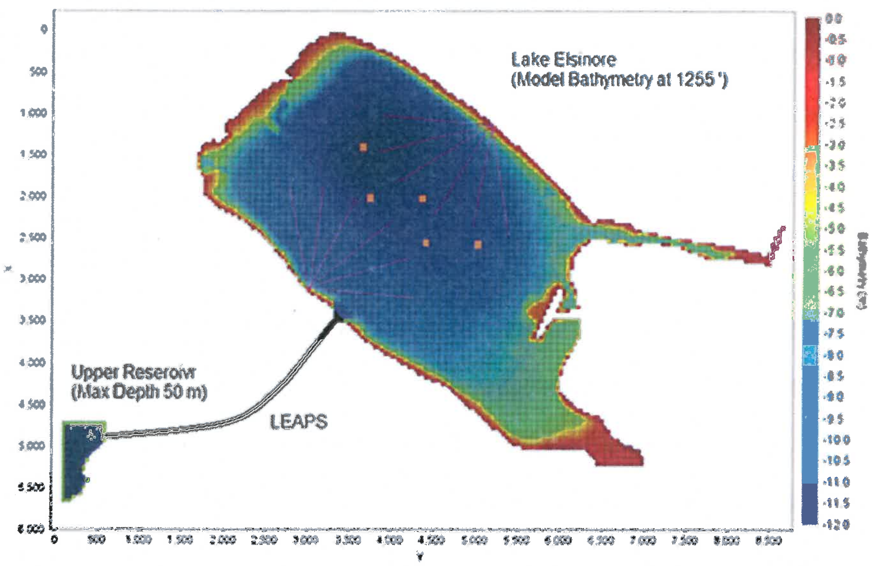

Fig. 2. Model grid and bathymetry (130 ft x 130 ft x 1 ft; 240,004 cells in computational domain at full pool). Axial flow pumps depicted as brown squares, approximate location of diffused aeration lines shown as light purple lines.

The model was calibrated to water column and water quality data available for the period from February 8, 2016 – August 31, 2018 (Amec Foster Wheeler, 2017, 2018); this period was selected for calibration and analysis based upon the availability of high quality monitoring data and the extreme conditions present in the lake over this time. Conditions included extremely low lake levels (<1233 ft) in 2016 with very high TDS concentrations (nearly 4,000 mg/L)[2] and very poor water quality conditions (concentrations of total N as high as 9.8 mg/L, total P nearly 0.5 mg/L, and chlorophyll a reaching 349 µg/L), followed by high runoff and marked improvements in lake level and water quality in 2017, and the return of drought conditions in 2018. The model accurately reproduced observed lake levels, with root mean-square error (RMSE) of 2.4 inches, accurately predicted TDS concentrations and water column temperatures (relative RMSE values of 3.7-4.9%), and reasonably reproduced total N and total P concentrations (relative RMSE values of 12.4 and 18.3%, respectively). The model reproduced general trends in chlorophyll a and DO although overall error levels were higher (relative RMSE values of 31.5 and 47.0% when

[2] mg/L = parts per million (ppm). One ppm is roughly equivalent to one second in 11.5 days.

normalized to mean concentrations, although lower errors of 21.9 and 12.3%, respectively, were calculated when RMSE values were normalized to concentration range). Notwithstanding the larger errors in predicted DO and chlorophyll a concentrations (and assuming no error in measured values), the model was considered adequate for a comparative analysis of water quality with and without operation of LEAPS.

Conclusions

The model was used to simulate the lake in its native condition (including operation of the axial flow pumps and diffused aeration system) and with LEAPS operation that included initial supplementation of up to 15,000 acre-feet of SWP water and annual inputs of approximately 300 acre-feet of SWP water to offset evaporative losses from the Upper Reservoir. The SWP water is of high quality, with only 10-18% of the total P concentrations and 20-50% of the total N concentrations of current water sources for the lake (San Jacinto River, local runoff and recycled water). The analysis specifically sought to address 3 objectives:

1. Quantify effects of LEAPS operation at different lake surface elevations on water quality in Lake Elsinore and identification of lake elevations when significant negative impacts would occur;
2. Assess impacts of pumping, transient storage in the Upper Reservoir, and hydropower generation on concentrations of total N, total P, cyanotoxins, DO and other constituents in return flows to Lake Elsinore during operation of LEAPS;
3. Evaluate strategies to *enhance* water quality in Lake Elsinore when compared with existing conditions.

Key findings from the study are briefly summarized below. Interested readers are encouraged to review the full report for additional details (Anderson, 2019).

Finding 1: The operation of LEAPS with supplementation up to 15,000 acre-feet of SWP water significantly increased the lake level and reduced volume-weighted concentrations of TDS, nutrients, chlorophyll a and microcystin across the range of lake elevations, with the greatest relative improvement achieved at lowest initial surface elevation and poorest water quality.

Three initial lake surface elevations were evaluated (1235, 1240 and 1247 ft) using the meteorological and hydrologic conditions from February 2016 – August 2018. For example, supplementation and operation at 1,235 ft initial elevation increased lake level by 4.3 ft, lowered average TDS by nearly 800 mg/L, and lowered total N, total P and chlorophyll A concentrations by 38-42% compared with Lake Elsinore in its native condition.

The operation of LEAPS had minimal effect on temperature gradients in the lake, (less than one-half degree Fahrenheit), and volume-averaged DO concentrations (average DO concentrations differed by -0.14 to 0.2 mg/L). Operation of LEAPS did modify to varying degrees vertical and horizontal distributions of DO. Two anticipated operational schedules for LEAPS (nighttime pumping/daytime hydropower generation or morning pumping/afternoon-evening hydropower generation) were evaluated, as well as two alternative widths of the lake inlet/outlet (I/O) (165 ft vs 490 ft); neither operation schedules nor I/O widths were found to significantly alter average water column conditions in Lake Elsinore. The operation of LEAPS across a lake surface elevation range of at least 1235-1253 ft is supported by model results.

Finding 2: Initial storage of water in the Upper Reservoir was found to have variable effects on water quality that increased with increasing retention time.

With regular weekday pumping and hydropower generation, the retention time of water in the Upper Reservoir was 1-2 days, and water quality followed quite closely that of Lake Elsinore, with very similar temperatures and concentrations of TDS and total nutrients (<1-2% difference in averaged values). The concentrations of DO, chlorophyll a and microcystin in the Upper Reservoir were generally lower than concentrations in Lake Elsinore (volume-averaged concentrations were 12.5, 8.5 and 26.6% lower, respectively, in the Upper Reservoir compared with Lake Elsinore). Increasing the duration of storage in the Upper Reservoir from approximately 2 days over the weekend under a typical schedule or longer yielded more significant differences, especially with respect to concentrations of chlorophyll a and DO. Volume-averaged concentrations of nutrients, DO and microcystin in Lake Elsinore were only very modestly changed, however, following flow of this water during hydropower generation due to the small volume compared with that present in the lake.

Finding 3: While not proposed as part of the license application for the project, augmentation to DO concentrations in return flows to the lake during hydropower generation was predicted to provide significant additional ongoing benefits to water quality beyond initial dilution with SWP water.

In addition to assessing water quality impacts of LEAPS operation, the potential for enhancement of water quality relative to existing conditions was also evaluated. Simulations indicated that LEAPS operation with DO augmentation to bring concentrations up to 10 mg/L in return flows increased the average DO concentration in Lake Elsinore at the low (1235 ft) initial elevation scenario from 5.49 mg/L to 6.99 mg/L (27% increase) that also helped distribute DO across the lake, including directly above the sediments. Increased DO would reduce fish kills, favorably shift biogeochemical cycling of nutrients and improve overall ecological conditions. The capacity for LEAPS to improve water quality is thought to be of value to the TMDL efforts at the lake.

References

Anderson, M.A. 2019. *Impacts of the Lake Elsinore Advanced Pumped-Storage (LEAPS) Project on Water Quality in Lake Elsinore.* Final Report to the Federal Energy Regulatory Commission, Washington DC, Project No. 14227. 79 pp + Appendix.

AMEC Foster Wheeler. 2017. *Lake Elsinore and Canyon Lake Watersheds Nutrient TMDL Monitoring 2016-2017 Annual Report.* Final Report to the Lake Elsinore & San Jacinto Watersheds Project Authority. 76 pp.

AMEC Foster Wheeler. 2018. 2017-18 *Lake Elsinore and Canyon Lake Nutrient TMDL In-Lake Monitoring Quarter 2 Report.* Quarterly Report to the Lake Elsinore & San Jacinto Watersheds Project Authority.32 pp.

Anderson, M.A. 2006a. *Technical Analysis of the Potential Water Quality Impacts of the LEAPS Project on Lake Elsinore.* Draft Final Report submitted to the Santa Ana Regional Water Quality Control Board. 30 pp.

Anderson, M.A. 2006b. *Heating, Cooling and Stratification during LEAPS Operation.* Draft Final Report submitted to the Santa Ana Regional Water Quality Control Board. 24 pp.

Anderson, M.A. 2007a. *Effects of LEAPS Operation on Lake Elsinore: Predictions from 3-D Hydrodynamic Modeling.* Draft Final Report submitted to the Santa Ana Regional Water Quality Control Board. 49 pp.

Anderson, M.A. 2007b. *Ecological Impacts from LEAPS Operation: Predictions Using a Simple Linear Food Chain Model.* Draft Final Report submitted to the Santa Ana Regional Water Quality Control Board. 22 pp.

Anderson, M.A. 2010. Bathymetric, Sedimentological and Retrospective Water Quality Analysis to Evaluate Effectiveness of the Lake Elsinore Recycled Water Pipeline Project. Draft Final Report to the Lake Elsinore & San Jacinto Watersheds Authority. 50 pp.

FERC. 2018. *Response to Additional Study Requests.* June 15, 2018. Washington, DC.

Hodges, B. and C. Dallimore. 2016. *Aquatic Ecosystem Model: AEM3D.* v.1.0 User Manual. HydroNumerics, Docklands, Victoria, Australia. 125 pp.